

ASPE Annual Meeting 2022

Bellevue, Washington, USA
10 – 14 October 2022

ISBN: 978-1-7138-6373-1

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2022) by American Society for Precision Engineering (ASPE)
All rights reserved.

Printed with permission by Curran Associates, Inc. (2023)

For permission requests, please contact American Society for Precision Engineering (ASPE)
at the address below.

American Society for Precision Engineering (ASPE)
3434 Edwards Mill Road, Suite 112-325
Raleigh, NC
27612

Phone: (984) 268-9756

www.aspe.net

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

Technical and Poster Sessions

Papers that lent themselves to significant verbal interaction have been selected for poster presentation. Authors will present their work during the poster sessions on Wednesday, October 12 from 1:30 PM – 3:00 PM and on Thursday, October 13 from 3:30 PM – 5:00 PM.

Session 1

Precision Controls and Mechatronics

Wednesday, October 12, 2022, 8:00 AM – 9:45 AM

Co-Chairs: David L. Trumper (Massachusetts Institute of Technology) and Stephen J. Ludwick (Aerotech, Inc.)

- 1. Pushing the Limits of Speed, Form Accuracy, Surface Finish, and Waviness of SPDT by Means of Fast Tool Servos**
Takeshi Hashimoto, **Jeffery W. Roblee**, Sam Roseman, Cindy Ding (AMETEK Precitech) Abstract Not Available
- 2. Decoupled, Closed-Loop, Multi-DoF Rotation of a Spherical Permanent Magnetic Dipole Actuator**
Tyler T. Hamer, Joshua Chabot (MIT Lincoln Laboratory); David L. Trumper (Massachusetts Institute of Technology) 1
- 3. Real-Time Command Generator for Dual-Stage Processing Machines**
Shingo Tajima (Tokyo Institute of Technology); **Burak Sencer** (Oregon State University) 7
- 4. Transcending the Acceleration-Bandwidth Trade-Off: Lightweight Precision Stages with Active Control of Flexible Dynamics**
Jingjie Wu, **Lei Zhou** (University of Texas at Austin) 12
- 5. A Model-based Control Framework for Microscale Selective Laser Sintering**
Heejin Kim, Chinedum Okwudire (University of Michigan); Joshua Grose, Aaron Liao, **Michael A. Cullinan** (The University of Texas at Austin) 18

Session 2

Precision Metrology and Characterization I

Wednesday, October 12, 2022, 10:00 AM – 11:30 AM

Co-Chairs: Jonathan D. Ellis (Micro-LAM, Inc.) and Kevin E. Elliott (Corning, Inc.)

- 1. An Ultra-Low-Loss Chip-Scale Torsion Balance**
Charles A. Condos, Aman R. Agrawal, Christian M. Pluchar, Dalziel Wilson (University of Arizona); Robert Ilic, Stephan Schlamming, Jon R. Pratt (National Institute of Standards and Technology) 24
- 2. A Miniature Electrostatic Force Balance for Laser Power Measurements**
Kumar Arumugam, Gordon A. Shaw (National Institute of Standards and Technology) 29
- 3. Precision Engineering for Gravitational Experiments**
S. Schlamming, L. Chao, V. Lee, D.B. Newell, J.R. Pratt (National Institute of Standards and Technology); C.C. Speake (University of Birmingham, UK) 34

4. Precision Sensing of Gravitational Acceleration

Jon R. Pratt, **Stephan Schlaminger**, Robert Ilic (National Institute of Standards and Technology); Dalziel Wilson, Charles A. Condos (University of Arizona); Felipe Guzman, Andrea Nelson (Texas A&M) 38

Session 3

Precision Engineering in Virtual and Augmented Reality

Thursday, October 13, 2022, 8:00 AM – 9:45 AM

Co-Chairs: Tim M. Dalrymple (Motion Systems Opto-Mechanical Consultant) and Phil Harvey (Microsoft)

1. Manufacturing Metrology for Alternative-reality Optical Displays

Peter J. de Groot (Zygo Corporation) Abstract Not Available

2. Microstructured Optical Fibers for Scanning Display Systems in Augmented Reality

Timothy M. Dalrymple (Motion Systems Opto-Mechanical Consultant) 44

3. Focus Tunable Lenses for AR/VR/MR – Advances in Formfactor and Weight

Roman Patscheider (Optotune Switzerland AG) Abstract Not Available

4. Use of Precision Engineering to Develop a High Volume Waveguide Manufacturing Solution Enabling a Smaller AR Display

Roy Patterson, Satish Sadam, Sebastian Kulesa, Bob Tekolste, Jeff Schmulen, Scott Carden (Magic Leap) 50

5. The Use of Augmented and Virtual Reality in a Large Precision Engineering Company

Thomas C. Weinlandt (ASML) Abstract Not Available

Session 4

Precision Metrology and Characterization II

Thursday, October 13, 2022, 10:00 AM – 11:30 AM

Co-Chairs: Steven R. Gillmer (MIT Lincoln Laboratory) and Felipe N. Guzman (Texas A&M University)

1. Advances in Optomechanical Inertial Sensing

Andrea Nelson, Yanqi Zhang (University of Arizona); Adam Hines, Felipe Guzman (Texas A&M University) 56

2. Precision Alignment Procedure for the tRexs Sounding Rocket Payload Optical Assembly Using A Portable CMM Arm

Bridget C. O’Meara, Ross C. McCurdy, James H. Tutt, Logan D. Baker, Nestor Pelaez Guillen, Randall L. McEntaffer (Pennsylvania State University); Drew M. Miles (California Institute of Technology); Joseph Weston (Lockeed Martin Space) 60

3. Hysteresis of Probes for On-Machine Measurements

Adam Woźniak, Marta Rępałska (Warsaw University of Technology) 65

- 4. Axial Shift Mapping for Absolute Metrology of X-ray Telescope Mirrors**
Hayden J. Wisniewski, Ian J. Arnold, and Brandon D. Chalifoux (The University of Arizona); Ralf K. Heilmann, Mark L. Schattenburg (Massachusetts Institute of Technology) 69

Session 5

Precision Design

Thursday, October 13, 2022, 1:30 PM – 3:15 PM

Co-Chairs: Leon Chao (National Institute of Standards and Technology) and Kumar Arumugam (National Institute of Standards and Technology)

- 1. Two Degree-of-Freedom Flexure Mechanisms with Variable Stiffness**
 Sam Shimohara, Ryan Lee, **Jonathan B. Hopkins** (University of California, Los Angeles) 75
- 2. Characterization and Alignment of the Flexure Mechanism for the New Kibble Balance at NIST**
Lorenz Keck, Frank Seifert, David Newell, Darine Haddad (National Institute of Standards and Technology); René Theska (Technische Universitaet Ilmenau) 80
- 3. Cost-Effective High-Precision Magnetically Levitated Positioning Stage Technology**
Jos de Klerk, Rob Verkooijen, Thomas van der Zijden, Ton Peijnenburg, Francesco Patti, Rob Boereboom (VDL ETG) 86
- 4. The Sample Positioning Stage for the Sapoti Nanoprobe at the Carnaúba Beamline at Sirius/LNLS**
Renan R. Gerales, Gabriel B. Z. L. Moreno, João L. de Brito Neto, H. C. N. Tolentino (Brazilian Synchrotron Light Laboratory (LNLS)); T. A. M. Ruijl, W. Aarden, P. Peters (MI-Partners) 91
- 5. A Massively Overconstrained and Statically Balanced Flexure Mechanism for a 20 kN Load Capacity**
 Jan J. de Jong, **Marijn Nijenhuis**, Dannis M. Brouwer (University of Twente) 98

Session 6

Precision Manufacturing

Friday, October 14, 2022, 8:00 AM – 9:45 AM

Co-Chairs: Stephen J. Furst (Smart Material Solutions, Inc.) and Ping Guo (Northwestern University)

- 1. Form Error Compensation of Freeform Surfaces by Gaussian RBF Interpolants**
Christopher Morgan (Moore Nanotechnology Systems, LLC) 102

2. **In-Situ Metrology and 3D Error Compensation for Precision Aspheres in Virtual Reality Viewing Optics**
Neil Naples (AMETEK Precitech);
Alex Sohn (Meta Reality Labs)Abstract Not Available
3. **Robotic Smoothing of Diamond Turning Signature on Optical Silicon**
Daniel R. Brooks, Jennifer Coniglio, Jessica DeGroot Nelson
(Optimax Systems, Inc.) 106
4. **Ultrafast Laser Stress Figuring Using On-Machine Differential Deflectometry**
Kevin A. Laverty, Marcos A. Esparza, Daewook Kim,
Brandon D. Chalifoux (University of Arizona) 112
5. **A Study of Surface Morphology Evolution in Fluid Jet Polishing**
Zhang Zili, Cheung Chi Fai, Wang Chunjin, Ho Lai Ting,
Guo Jiang (The Hong Kong Polytechnic University) 116

Session 7

Micro Nano

Friday, October 14, 2022, 10:00 AM – 11:45 AM

Co-Chairs: Michael A. Cullinan (The University of Texas at Austin) and Robert M. Panas (Bright Silicon Technologies)

1. **Nanophotonic Technology for Optical Imaging, Computing and Communication**
Arka Majumdar (University of Washington-Seattle)Abstract Not Available
2. **Low-Cost and High-Throughput Printing of Polymeric Nanostructures via Projection of Superluminescent Light**
Jungho Choi, Sourabh K. Saha (Georgia Institute of Technology) 122
3. **Design Concerns for Tip-Based Measurement Towards Process Metrology in Roll-to-Roll Nanomanufacturing**
Liam G. Connolly, Barbara Groh, James A. Garcia,
Michael A. Cullinan (The University of Texas at Austin)..... 126
4. **Design and Manufacturing of Microscale Mechanical Logic Circuits**
Hilary A. Johnson, Alexander H. Slocum (Massachusetts Institute of Technology); John Cortes, Logan Bekker (Lawrence Livermore National Laboratory); Robert M. Panas (Bright Silicon Technologies); Amin Farzaneh, Jonathan B. Hopkins (University of California Los Angeles).....Abstract Not Available
5. **Fabrication of High Average Power Output Diffraction Gratings for Ultrafast Pulsed Laser Application**
Vidhukiran Venkataraman, Harnjoo Kim, Jungho Choi, Suvrat Jain,
Sourabh. K Saha (Georgia Institute of Technology) 132

Poster Sessions

Poster Session 1

Wednesday, October 12, 2022, 1:30 PM – 3:00 PM

Aerospace Engineering

- 1. Monitoring and Analysis on Aircraft CFRP Drilling Process**
Song Hyeon Ju, Hae-Jin Choi (Chung-Ang University); Jong Wan Ko,
Seong Hyeon Kim, Kangwoo Shin, Tae-Gon Kim, Seok-Woo Lee,
Jungsoo Nam (Korea Institute of Industrial Technology)..... 136

Controls and Mechatronics

- 1. Study on Display-Panel Transfer Robot Path Error Compensation System Incorporated with ILC**
Minsu Jo, Ilgyun An, Jeahong Sim, Kihyun Kim,
Hyoyoung Kim (Tech University of Korea)..... 142
- 2. DirectDrive3D – Advanced Control Technology for Ultra-Precision Technology**
Christian Wenzel, Philipp Kosse, Michael Berens, Klaus Schweizer, Matthias Brozio (Innolite GmbH) 146
- 3. Magnetically Levitated XYθ Stage Using a Bearingless Motor Design**
Abdel Fahmy, **Laura Homiller**,
Lei Zhou (The University of Texas at Austin) 150
- 4. Laser Interferometry System for Long-Range Precision Displacement Sensing**
Ian L. Heyman, Lei Zhou (The University of Texas at Austin)..... 154
- 5. Analysis of the Effects of Robot Compliance Errors on Robotic Drilling Systems and Offline Compensation**
Jinho Lee, Taehwa Hong, Tae-Gon Kim, Jungsoo Nam, Seong Hyeon Kim
(Korea Institute of Industrial Technology (KITECH))..... 159
- 6. Mechanical Displacement Measurement Under Varying Air Supply Control Techniques**
Benjamin H. Jacobs, Daniel C. Thompson (Praecis Inc.)..... 163

Micro and Nano Technologies

- 7. Enabling More Efficient Printing of 2PP Mechanical Logic Structures Through Novel Photoinitiator**
Weilin Liao, Magi Mettry, Matthew Worthington, Swetha Chandrasekaran,
John Cortes (Lawrence Livermore National Laboratory);
Robert Panas (Bright Silicon Technologies) 169

8. Functional Analysis of a Polariscope Tool for the Evaluation of Strain in Roll-to-Roll Nanofabrication Barbara Groh, Liam G. Connolly, Michael A. Cullinan (The University of Texas at Austin).....	174
9. Development of a Meniscus Dragging Coating Approach for Microscale Selective Laser Sintering Aaron Liao, Dipankar Behera, Michael A. Cullinan (The University of Texas Austin).....	179
10. Mechanical Oscillators for Optical Mirror Modulation Vy Tran, Stuart T. Smith (University of North Carolina – Charlotte)	182
11. Process Development and In-situ Control of Conformable, Capillary-driven, Continuous Roll-to-Roll Nanoimprint Lithography Parth N. Pandya, Shrawan Singhal, Noah Graff, Ovadia Abed, S.V. Sreenivasan (The University of Texas at Austin).....	189
12. Spacial Positioning Correction for Multi-Axis Nanopositioning Stages Graham Bartlett, Alison C Raby (Prior Scientific Instruments Limited); Alistair Forbes, Edward Heaps, Andrew Yacoot (National Physical Laboratory).....	195

Precision Design

1. Design Considerations for Additive Manufacturing of Machine Tool Structural Components Tyler Poon, Justin L. West, Emma D. Betters, Tony Schmitz (University of Tennessee, Knoxville), Scott Smith, Christopher T. Tyler (Oak Ridge National Laboratory)	199
2. Challenges in the Verification of Forced Air Cooling in Precision Machines Feiyu Geng, Bart Koolmees, Nico Tan, Kees Verbaan, Erik Gerrit Hijkoop (NTS-Group).....	205
3. 4-DOF Exactly-Constrained KB Set for Hard X-Ray Nanofocusing with Multi-Stripe Elliptical Mirrors at MOGNO Beamline Gabriel B. Z. L. Moreno, Cassiano S. N. C. Bueno , Artur C. Pinto, Mailson S. Souza, André S. Rocha, Leandro M. dos Santos, João P. S. Furtado, Gabriel R. B. Ferreira, Izabela Z. Lago, Yuri R. Tonin, Nathaly L. Archilha (Brazilian Synchrotron Light Laboratory (LNLS)).....	209
4. Through Pellicle Inspection: EUV Microscope Engineering Design Summary Dmytro Zaytsev , Arnaud Allézy, Markus Benk, Michael Dickinson, Ryan Miyakawa, Patrick Naulleau, Senajith Rekawa (Lawrence Berkeley National Laboratory)	214
5. Precision LED Mount Jihye Skylar Kim , Peter Ferenz (ASML).....	219

6. **Precision Load Lock Door for Lyophilization Systems**
Ryan Flores, Steven Burcat, Rohan Kadambi, , Alex Slocum, Bernhardt Trout
(Massachusetts Institute of Technology); Josh Dittrich (Startsomething LLC)... 223
7. **Design and Testing of an Ultra-Precision Biconic Air Bearing**
Byron R. Knapp, Dan Oss, Dave Arneson (Professional Instruments Company);
Brian P. O'Connor (Aerotech, Inc.) 228
8. **25,000 Optical Fiber Positioning Robots for Next-Generation Cosmology**
Joseph H. Silber, David J. Schlegel, Robert W. Besuner, Julien Guy (Lawrence
Berkeley National Laboratory); Ricardo Araujo, Jean-Paul Kneib, Markus
Thurneysen (École Polytechnique Fédérale de Lausanne (EPFL)); Charles
Baltay (Yale University); Emily Farr (University of Colorado, Boulder); Claire
Poppett (University of California Berkeley), **Travis A. Mandeville**, Sarah Tuttle
(University of Washington, Seattle); Michael Schubnell (University of Michigan,
Ann Arbor)..... 233

Surface Characterization and Applications of Measurement Science

1. **Ultra-sensitive RGA system**
John Timmermans, **Erik Gerrit Hijkoop**, (NTS-Group Development) 239
2. **Replication of Functional Surfaces Micro-structured by EDM**
Eckart Uhlmann, Mitchel Polte, **Jonas Ludwig**, Robert Bolz (Technische
Universität Berlin) 243
3. **Surface Defect Detection Method Based on Gabor Filter and Surface Normal in 3D Point Cloud Data**
Eddie T. Lee, Zhaoyan Fan, Burak Sencer (Oregon State University) 247

Poster Session 2

Thursday, October 13, 2022, 3:30 PM – 5:00 PM

Metrology Systems

1. **Influence of the Touch-Trigger Probe Qualification Procedure in On-Machine Measurements**
Marta Rępańska, **Adam Woźniak** (Warsaw University of Technology)..... 253
2. **Refining Measurements of an SI-Traceable Self-Calibrating Electronic Torque Standard**
Zane D. Comden, John Draganov, Stephan S. Schlamming, Frank Seifert,
Charles Waduwarage Perera, David Newell, Leon Chao (National Institute of
Standards and Technology) 258
3. **Repeatability and Reproducibility Studies for Structured Light Scanning**
Leah J. Jacobs, **Tony Schmitz** (University of Tennessee, Knoxville) 263

4. High-Precision Stress Measurement in Thin Films Mallory M. Whalen , Ralf K. Heilmann, Mark L. Schattenburg (Massachusetts Institute of Technology).....	268
5. Dimensional Metrology in Determination of G with BIPM’s Torsion Balance V. Lee , S. Schlamminger, C.M. Shakarji, L. Chao, D.B. Newell, J.R. Pratt (National Institute of Standards and Technology); C.C. Speake (University of Birmingham)	272
6. Trinocular Vision System for Pose Determination Mohammed A. Isa , Mojtaba A. Khanesar, Richard Leach, David Branson, Samantha Piano (University of Nottingham).....	277
7. Application of Optical Sensors – An Enabler for Quality Inspection with Variable Inspection Rate Felix Balzer and Thomas Weigert (Hexagon Manufacturing Intelligence).....	283
8. Metallurgical Property Profiling of Machined Surface Layer for Microstructural Prediction in Subtractive and Additive Manufacturing Jungsub Kim, HeeBum Chun, Bruce Tai, ChaBum Lee (Texas A&M University).....	288
9. Integration of a 3-axis Hallsensor with a CMM Dave Yeagly (Lawrence Berkeley National Laboratory)	292
10. High Accuracy Calibration Using Multiple Angular Encoders with Mounting Tolerance Analysis Jinsoo Choi , Hongki Yoo (Korea Advanced Institute of Science and Technology); Hyunchang Kim, Dongwoo Kang (Korea Institute of Machinery and Materials)	296

Precision Manufacturing

1. Structural Dynamics Modeling and Machine Learning for Integral Blade Rotor Milling Gregory M. Corson, Tony Schmitz (University of Tennessee, Knoxville); Jaydeep Karandikar (Oak Ridge National Laboratory).....	300
2. Fabrication of Freeform Silicon Carbide Components by Hybrid Manufacturing Jake Dvorak, Dustin Gilmer, Ross Zamoski, Aaron Cornelius, Tony Schmitz (University of Tennessee, Knoxville).....	306
3. Preliminary Cutting Force and Tool Wear Study for Micro-Patterned Turning Inserts Ryan A. Garcia, Tony L. Schmitz (University of Tennessee, Knoxville); Brian K. Canfield; Alexander Y. Terekhov, Trevor Moeller, Lino Costa (University of Tennessee Space Institute)	311

4. Large-Scale Hybrid Manufacturing of Freeform Metal Components Bradley H. Jared , Aaron Cornelius, Eduardo Miramontes, Tiffany P. Quigley, Joshua Penney, Joshua Kincaid, Ross Zamerowski, Gregory M. Corson, Leah Jacobs, Timothy No, Tony L. Schmitz, William R. Hamel (University of Tennessee, Knoxville)	317
5. Research on Non-Contact Overall Length Measurement of Elongated Objects at the Processing Worksites Jingwei Wang , Ryushiki Mori, Takanori Yazawa, Tatsuki Otsubo, Toshiaki Yasaka (Nagasaki University).....	319
6. Investigation of Additive Manufactured Tungsten Carbide-Cobalt Tool Electrodes for Sinking EDM Eckart Uhlmann, Mitchel Polte, Robert Hörl , Thomas Braun, Robert Bolz (Technische Universität Berlin)	323
7. Design and Control of a Wafer Handling Module for Hybrid Bonding Dahoon Ahn (Seoul National University of Science and Technology); Hak-Jun Lee (Korea Institute of Industrial Technology).....	329
8. Extremum Seeking Control-based Real-time Optimization of Spindle Speed in Machining Kaan Bahtiyar , Burak Sencer (Oregon State University)	333
9. LIMS Data Collection and Analysis for Machining Monitoring Tobechukwu D. Nwabueze, Tony L. Schmitz (University of Tennessee, Knoxville); Nat Frampton (LECS Energy LLC); Christopher Tyler, Jaydeep Karandikar (Oak Ridge National Laboratory).....	339
10. Elastic Emission Machining (EEM) Toolpathing Methods for Optimizing Surface Finish on Three and Four Axis Machines Jacob Guymon (North Carolina State University).....	Abstract Not Available
11. Optical Simulation of Hierarchical Surface Structure Design for Structural Coloration Yaoke Wang , Ping Guo (Northwestern University)	343
12. High-Speed Catalyst-Referred Etching of Gallium Nitride Assisted by Ultraviolet Light Irradiation Kiyoto Kayao , Daisetsu Toh, Kazuto Yamauchi, Yasuhisa Sano (Osaka University)	349
13. Surface Planarization of Polycrystalline Silicon Carbide by Catalyst- Referred Etching Kohei Futamura , Daisetsu Toh, Kazuto Yamauchi, Yasuhisa Sano (Osaka University)	353
14. A Study of Surface Integrity in Ultra-Precision Grinding of Al/SiC Metal Matrix Composites Sai Guo, Chi Fai Cheung, Zili Zhang , Lai Ting Ho (The Hong Kong Polytechnic University); Bi Zhang (Southern University of Science and Technology, Shenzhen).....	357

15. Characterization of Aerodynamic Effects and Unbalance in Rotor Dynamics Whirl Orbit	
Fabian Stoop , Konrad Wegener (ETH Zürich); Josef Mayr (inspire AG).....	361
16. Fundamental Evaluation of Cooling Characteristics of Cooling Structures for High-Speed Aerostatic Spindle	
Shumon Wakiya , Jumpei Kusuyama, Yohichi Nakao (Kanagawa University); Dmytro Fedorynenko (Tohoku University)	366
17. Towards Digital Ultra-Precision Manufacturing	
Lars Schönemann , Oltmann Riemer (University of Bremen).....	371